U. S. DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS

X-RAY PROTECTION

HANDBOOK, BUREAU OF STANDARDS, No. 15

U. S. DEPARTMENT OF COMMERCE
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PREFACE

Upon the suggestion of the secretaries of the International Safety Committee, Dr. G. W. C. Kaye and Dr. Stanley Melville, the Advisory Committee on X-Ray and Radium Protection was formed in the United States for the purpose of preparing a unified set of safety recommendations. In order to have a committee not too cumbersome and yet thoroughly representative of the several phases of the art, two members were appointed by each radiological society, two by the manufacturers of X-ray equipment, and one by the Medical Association. The presidents of the radiological societies were each asked to appoint one physicist and one radiologist. The members representing the manufacturers were selected by the manufacturers through nomination and ballot.

The following members compose the committee:

Representing International Safety Committee and National Bureau of Standards:
LAURISTON S. TAYLOR.
Representing American Roentgen Ray Society:
H. K. PANCOAST, M. D., University of Pennsylvania Hospital.
J. L. WEATHERWAX, physicist, Philadelphia General Hospital.
Representing Radiological Society of North America:
R. R. NEWELL, M. D., Stanford University Hospital.
G. FAILLA, physicist, Memorial Hospital.
Representing the American Medical Association:
FRANCIS CARTER WOOD, St. Lukes Hospital, New York, N. Y.
Representing X-ray equipment manufacturers:
W. D. COOLIDGE, associate director, research laboratory, General Electric Co.
W. S. WERNER, secretary of Kelley-Koett Manufacturing Co., Covington, Ky.

The committee recognizes that future development of the art may require changes in these recommendations. Since the existence of the committee is not permanent, it recommends that any future changes of these proposals be made by the National Bureau of Standards after consultation with proper and recognized committees.

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X-RAY PROTECTION

I. PROTECTION FROM X RAYS

1. GENERAL RECOMMENDATIONS

A. DEFINITIONS

1.01. Throughout these recommendations the word "shall" is used to indicate necessary requirements, while the word "should" indicates advisory requirements to be applied when possible.

1.02. The "lead equivalent" of a protective material is defined as the thickness of lead which will have the same true absorption for a given X-ray beam as the protective material.

1.03. The "protection coefficient" of a protective material is the ratio of the thickness of lead to the thickness of the material which absorbs a given X-ray beam to the same extent.

1.04. In expressing the protection coefficient the X-ray voltage at which the measurement is made shall be given for all materials owing their high absorptive power to other than lead content. For determining the protection coefficient either a photographic substitution or ionization substitution method, which takes the true absorption into consideration, shall be used.

1.05. For the purpose of specifying high-tension spark-over distances, the following table gives the approximate needle point spark-gap distance for peak voltages up to 300 kv (760 mm atmospheric pressure and 20° C.).

TABLE 1

Kilo volts (peak)	Needle point gap		Kilo volts (peak)	Needle point gap	
	cm	*Inches*		*cm*	*Inches*
5	0.42	0.17	120	19.8	7.81
10	.85	.33	130	22.0	8.65
15	1.30	.51	140	24.1	9.48
20	1.75	.69	150	26.1	10.3
25	2.20	.87	160	28.1	11.1
30	2.69	1.06	170	30.1	11.9
35	3.20	1.26	180	32.0	12.6
40	3.81	1.50	190	33.9	13.3
45	4.49	1.77	200	35.7	14.0
50	5.20	2.05	210	37.6	14.8
60	6.81	2.68	220	39.5	15.5
70	8.81	3.47	230	41.4	16.3
80	11.1	4.36	240	43.3	17.0
90	13.3	5.23	250	45.2	17.8
100	15.5	6.10	300	54.7	21.6
110	17.7	6.96			

1.06. The term "direct radiation" shall include all radiation other than the useful beam emanating from the X-ray tube anode or the inside of a tube or tube container. The "useful beam" of X rays shall include that part of the radiation used in examination or treatment. The term "scattered radiation" shall refer to the secondary radiation from the patient and any parts of the room or apparatus.

B. ROOMS FOR X-RAY APPARATUS

1.07. X-ray and control rooms shall be so located as to avoid dampness and to provide ventilation and light. This requires that, in general, such rooms be on or above the ground floor. All rooms should be decorated in light colors.

1.08. Forced ventilation should be provided to remove nitrous gases and ozone from all rooms occupied by patients or operators. This ventilation should be such that fresh air enters the room at or near the floor, and that stale air is removed near the ceiling at the opposite side of the room.

1.09. Rooms containing high-tension generators, all tube inclosures or other places where high tension is present shall be provided with suction ventilation to remove nitrous or other gases.

1.10. All X-ray rooms (except for dental radiography) or booths shall be lined throughout with sheet lead or equivalent material of assured quality, uniformity, and permanency, care being taken that there be complete overlapping of all joints. "Protective plasters" and lead rubber wall board are considered to be unsatisfactory for providing protection exceeding 1 mm. lead equivalent.

1.11. Protective lead coverings for X-ray rooms and booths shall not be perforated by nail holes, etc., unless such holes are adequately covered with lead.

1.12. Corner construction at the floor and ceiling of lead-protected rooms or booths shall provide at least the same degree of protection as the remainder of the walls.

1.13. The protective lead covering of any door leading to a treatment or examination room or booth shall overlap so as to adequately prevent the passage of X rays.

1.14. The following lead equivalents are recommended as adequate:

TABLE 2

X-rays generated by peak voltages not in excess of—	Minimum equivalent thickness of lead
kv	*mm*
75	1.0
100	1.5
125	2.0
150	2.5
175	3.0
200	4.0
225	5.0
300	9.0
400	15.0
500	22.0
600	34.0
900	----------

C. MARKING OF PROTECTIVE DEVICES

1.15. All X-ray protective materials shall be indelibly marked by the manufacturer in such a manner as to readily show the lead equivalent thickness of the material. (See Table 2.) For protective materials containing other than

lead to cause the high absorption, the voltage at which the equivalence applies shall be given.

1.16. All X-ray tube inclosures made of lead glass, all metal shields, and oil-immersed X-ray tube containers shall be marked by the manufacturer in such a manner as to readily show the equivalent lead thickness of the protective material.

D. TUBE INCLOSURES

1.17. A protective inclosure shall surround all X-ray tubes so as to prevent the escape of direct radiation from the bulb and cathode and anode necks.

Classification of X-Ray Installations

1.18. Class A. X-ray installations for diagnostic purposes at voltages up to 130 kv peak.

Class B. X-ray installations for superficial therapy at voltages up to 140 kv peak.

Class C. X-ray installations for voltages from 140 to 250 kv peak, in which the X-ray tube is housed in an inclosure affording the requisite protection from all direct radiation.

2. SPECIAL REQUIREMENTS FOR APPARATUS OF CLASS A

(X-ray installations for diagnostic purposes at voltages up to 130 kv peak)

E. PROTECTION FROM DIRECT RADIATION

2.01. A protective inclosure shall surround the X-ray tube bulb, and the arms for a distance of 4 inches from the bulb, so that direct radiation is shielded off in all directions. Open bowls shall not be used.

2.02. In the case of X-ray tubes having built-in protection, the equivalent lead thickness shall conform to Table 2, and shall shield off all direct radiation.

F. PROTECTION OF PATIENT

2.03. An aluminum filter, at least 0.5 mm thick, shall be permanently mounted in all fluoroscopic and radiographic tube inclosures.

2.04. The diaphragm of the tube container shall have a permanent covering of asbestos board at least 0.5 mm thick placed between the tube and filter next to the filter.

It is recommended that for prolonged fluoroscopic work an accumulative timing device be used which will either indicate or turn off the apparatus when the total exposure exceeds a certain previously determined limit—given in one or in a series of exposures—assuming the same body area exposed.

G. PROTECTION OF PHYSICIAN AND PERSONNEL

Protection from Direct Radiation

2.05. The fluorescent screen shall be covered with plate lead-glass having an equivalent lead thickness of at least 1.5 mm.

2.06. Protective gloves shall have an equivalent lead thickness of at least 0.5 mm, and shall insure protection to the whole hand—outer surface, palm, fingers, and wrist.

2.07. Protective aprons worn by the physician or technician shall have an equivalent lead thickness of at least 0.5 mm.

2.08. Aprons may be worn by the operator or may be permanently attached to the radioscopic apparatus in such a manner as to provide suitable protection.

2.09. The tube protective inclosure shall be provided with an adjustable diaphragm which, when open to its fullest extent, leaves a margin of one-fourth inch of unilluminated fluorescent screen with the screen at its fullest distance from the tube. Diaphragm and screen should, when possible, be mounted on a common support so the two will always move together.

2.10. The fluorescent screen frame shall contain a protective material (1.5 mm equivalent) overlapping the protective glass one-fourth inch and extending at least 6 inches beyond the edges of the glass.

Protection from Scattered Radiation.

2.11. To protect the physician from secondary radiation during fluoroscopic work, the following protective measures should be provided:

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(*a*) *Upright fluoroscope* (*standing or sitting patients*).—Protective shield of at least 1.5 mm lead equivalent, fastened to the fluoroscope and extending from one-fourth inch inside the border of the fluorescent screen to such a height above the floor that the physician's legs and body will be thoroughly shielded for all positions of the screen.

Wings of protective material (1.5 mm equivalent) shall be provided to extend 6 inches to each side and top of the fluorescent screen and shall overlap the screen cover glass one-fourth inch. (See sec. 2.07.)

(*b*) *Horizontal fluoroscope.*—Protective shields (1.5 mm lead equivalent) shall be placed (rigid or movable), one on each side of the screen.

Shields of flexible material (1.5 mm lead equivalent) should extend from the above-mentioned shields to the floor and should either move with the fluorescent screen and tube or cover the entire length of the table.

(*c*) *Tilting fluoroscope.*—Wherever practicable, the protective features of sections (*a*) and (*b*) above should be followed out.

2.12. Radiographic and radioscopic rooms shall be lined throughout with at least 0.5 mm of sheet lead or equivalent material of assured quality, uniformity, and permanency.

Exception.—This may be omitted only on outside walls and sides adjacent to unoccupied rooms.

2.13. To protect the operator and personnel, control apparatus for radiographic work should be in an adjacent room which provides protection equivalent to at least 0.5 mm of lead. Control operators should be behind such protection during all radiographic exposures, and during all radioscopic work when practicable.

2.14. When it is impracticable to place the control apparatus in an adjacent room, as in paragraph 2.13, it may be inclosed in a lead-lined booth within the radiographic room.

2.15. Either control room or booth shall be provided with a suitably large lead-glass window of 2.0 mm lead equivalent.

2.16. The use of movable upright protective screens is dangerous and shall be discontinued.

2.17. When thermionic rectifiers are used they shall be either placed in a separate room or surrounded by material of 0.1 mm lead equivalent.

3. SPECIAL REQUIREMENTS FOR APPARATUS OF CLASS B

(X-ray installations for superficial therapy at voltages up to 140 kv peak)

H. PROTECTION FROM DIRECT RADIATION

3.01. A protective inclosure shall surround the entire X-ray tube so that direct radiation is shielded off in all directions by protective material of 2.5 mm lead equivalent.

3.02. This equivalent thickness may be reduced by an amount equal to the thickness of the lead lining of the room, except that in no case shall less than half of the lead protection be provided by the tube inclosure.

3.03. In the case of X-ray tubes having built-in protection or oil-immersed tubes in protective tanks, the protection shall be equivalent to that in Table 2. Where the built-in protection is insufficient, additional protection in any direction shall be added up to the required amount.

3.04. When the X-ray tube is so arranged that the radiation can be taken off in only one fixed direction, a sheet of lead 2.5 mm thick shall be placed in the path of the direct and useful beams, on the floor, wall, or ceiling opposite the diaphragm. This lead sheet shall extend 1 foot in all directions beyond the edge of the X-ray beam, determined by the largest possible aperture in the tube inclosure.

3.05. When the X-ray tube is so arranged that radiation can be taken off in several directions all parts of the room which may possibly be reached by the direct or useful beam of radiation shall be lined with sheet lead 2.5 mm thick. The lead lining of this thickness shall extend 1 foot beyond the edge of the beam for any position of the tube inclosure with its largest possible diaphragm aperture. When there is any doubt as to the limits of the beam the whole room should be lined with 2.5 mm of lead.

3.06. Protection from direct and useful radiation as indicated in paragraphs 3.04 and 3.05 may be omitted only on sides adjacent to permanently unoccupied rooms or outside building walls.

I. PROTECTION FROM SCATTERED RADIATION

3.07. In the case of paragraphs 3.04 and 3.05, the entire remaining portions of the room shall be lined with sheet lead 1.5 mm thick.

3.08. All control apparatus shall be located in an adjacent room or in a completely inclosed, well-ventilated booth lined with 2.5 mm lead. Such a room or booth shall be provided with a suitably large protective glass window or windows of 2.5 mm lead equivalent, so placed as to afford ready view of the patient and meters while the operator is in a normal and comfortable position.

3.09. The tube container and treatment table should be so arranged that the useful beam points away from the technician's booth, offices, etc.

3.10. When thermionic rectifiers are used they shall be either placed in a separate room or surrounded by protective material of 0.1 mm lead equivalent.

3.11. There shall be mounted in the diaphragm of the tube container, between the tube and the filter, a layer of asbestos board at least 0.5 mm thick to prevent a melted target from falling upon a patient.

4. SPECIAL REQUIREMENTS FOR APPARATUS IN CLASS C

(X-ray installations for voltages from 140 to 250 kv peak, in which the X-ray tube is housed in an inclosure affording the requisite protection from all direct radiation.

J. PROTECTION FROM DIRECT RADIATION

4.01. The X-ray tube shall be completely inclosed in a protective inclosure so that all direct radiation is shielded off in all directions by protective material having lead equivalent as given in Table 2.

4.02. This equivalent thickness may be reduced by an amount equal to the thickness of the lead lining of the room except that in no case shall less than half of the lead protection be provided by the tube inclosure. (See pars. 4.05, 4.06, and 4.08.)

4.03. The diaphragm of the tube container shall have a permanent covering of asbestos board at least 0.5 mm thick, placed between tube and filter, next to the filter.

4.04. In the case of tube containers for water-cooled tubes, the diaphragm shall be sealed water-tight.

4.05. When the X-ray tube is so arranged that the radiation can be taken off in only one fixed direction, a sheet of lead of thickness in accordance with Table 2 shall be placed in the path of the direct or useful beam on the floor, wall, or

ceiling opposite the diaphragm. This lead sheet shall extend 1 foot in all directions beyond the border of the X-ray beam determined by the largest possible aperture in the tube inclosure.

4.06. When the X-ray tube is so arranged that radiation can be taken off in several directions, all parts of the room which may possibly be reached by the direct or useful beam of radiation shall be lined with sheet lead in accordance with Table 2. The lead lining of this thickness shall extend 1 foot beyond the edge of the beam for any position of the tube inclosure with its largest possible diaphragm aperture. When there is any doubt as to the limits of the beam, the whole room should be lined with lead in accordance with Table 2.

K. PROTECTION FROM SCATTERED RADIATION

4.07. In the case of paragraphs 4.05 and 4.06, the entire remaining portions of the room shall be lined with sheet lead having a thickness of 1 mm. less than the values specified in Table 2.

4.08. All control apparatus shall be located in a separate room.

4.09. Such control rooms shall have a protective glass window or windows of the same lead equivalent as the wall and should be so located that the operator may, while in a normal and comfortable position, have a ready view of the patient and meters.

4.10. When thermionic rectifiers are used, they shall be placed either in a separate room or surrounded by protective material of 0.2 mm lead equivalent.

II. ELECTRICAL PROTECTION

5. GENERAL ELECTRICAL SAFEGUARD RULES FOR INSTALLATION OF ALL X-RAY APPARATUS

5.01. X-ray installations may be connected to power mains by suitable, approved, plug and cable if the input corresponding to the rated capacity of the fused mains does not exceed 6.5 kva. In the use of plug and cable, the voltage and wattage rating of each shall be clearly and permanently

indicated. Leads to such apparatus shall be according to the regulations of the National Electrical Code.

5.02. If the power input under paragraph 5.01 exceeds 6.5 kva, the X-ray apparatus shall be permanently connected to the mains by means of an approved inclosed switch. A double-pole switch shall be used for direct and single phase current and a triple-pole switch for 3-phase current. In the use of a 220-volt 3-wire system the neutral shall be unfused.

5.03. If a transformer, rotary-converter, or motor-generator set be interposed between the mains and the X-ray apparatus, a suitable switch shall be inserted in the line between same and any X-ray apparatus.

5.04. The switch referred to in paragraphs 5.02 and 5.03 shall be secured by a locking device or by gravity in the off position, and shall be inclosed in a suitable grounded metal box.

5.05. A foot switch used as an operating switch for the X-ray transformer shall be in series with an auxiliary switch located on the control panel.

5.06. A foot switch shall have a rigid shield above the button so arranged that the switch can not be closed by accidentally stepping upon it.

5.07. A foot switch or hand switch shall be so constructed that for operation it is required to be held on. No locking device shall be permitted. If a foot or hand switch operates through a relay, the relay shall open upon release of the foot switch.

5.08. A time switch used as an operating switch for the X-ray transformer shall be in series with an auxiliary switch located on the control panel.

5.09. All X-ray apparatus shall be provided with a quick-acting, magnetic overload circuit-breaker interposed between the transformer and the supply circuit. This should preferably be an integral part of the apparatus and permanently installed therein.

5.10. The value of the tripping current shall be adjustable and clearly indicated on the circuit-breaker. For diagnostic apparatus the tripping current of the breaker shall be adjusted to a 40 per cent overload on the primary of the transformer, based on the maximum working voltage and

current. For therapy apparatus the tripping current shall be adjustable to 20 per cent overload on the primary.

5.11. The installation of water coolers shall comply with all regulations pertaining to high-tension equipment and high-tension conductors.

6. ROOMS FOR X-RAY EQUIPMENT

6.01. All high-tension generators shall be made inaccessible by means of an insulating barrier or a grounded metal barrier or shall be installed in a separate room. In any case, a switch shall be so arranged in the transformer primary circuit that the transformer will be immediately disconnected when the door leading to such an inclosure is opened. Furthermore, it shall be impossible to close this switch except from outside the inclosure after the door is closed.

6.02. In case of such inclosures for valve tube equipment having condensers in the high-tension circuit, there shall be, in addition to the specification in paragraph 6.01, a device so arranged that both sides of the high-tension system are automatically grounded when the door to the inclosure is opened in excess of 18 inches.

6.03. When the X-ray generator is self-contained in a wooden inclosure wherein the spark-over distances are in accordance with paragraphs 7.02, 7.03, and 7.04, and where no exposed high-tension leads are accessible or less than 7.5 feet above the floor, then paragraph 6.01 shall be invalid.

6.04. No control room shall be so separated from the treatment or examination room that the person operating the control panel does not have at all times a clear view of such treatment or examination room.

6.05. In the case of fluoroscopic equipment, where the generating apparatus is controlled by means of a foot switch used in accordance with paragraphs 5.05, 5.06, and 5.07, the control room may be separated from the fluoroscopic room. In such a case, there shall be in the examining room a device which indicates automatically and continuously during the time that the transformer primary switch located on the control board is closed.

6.06. If an X-ray generator be permanently installed in a therapy or diagnostic room, so that its high-tension termi-

nals are less than 7.5 feet above the floor, it shall be surrounded either by an earthed metal barrier or insulating barrier in accordance with paragraphs 7.02, 7.03, and 7.04.

7. INSULATED HIGH-TENSION BARRIERS

7.01. A grounded metal grid or screen may be used as a protective barrier if the mesh area does not exceed one-half inch square.

7.02. For X-ray apparatus earthed at one pole, a protective barrier of insulating material, including the air space between the latter and any high-tension part, shall provide an insulation necessary to withstand twice the maximum operating voltage and shall in no case be placed nearer to any high-tension part than the equivalent needle point spark-gap distance, as given in Table 1, corresponding to the maximum operating voltage.

7.03. For X-ray apparatus with the neutral of the high-tension generator permanently grounded through a low resistance, the protective barrier, including the air space between the barrier and any high-tension part, shall provide an insulation necessary to withstand the total maximum operating voltage, and in no case be placed nearer to any high-tension part than the equivalent needle point spark-gap distance, as given in Table 1, corresponding to one-half the maximum operating voltage.

7.04. For X-ray apparatus with no part of the high tension grounded, the protective barrier, including the air space between barrier and any high-tension part, shall provide an insulation necessary to withstand twice the total maximum operating voltage, and in no case be placed nearer to any high-tension part than the equivalent point spark-gap distance, as given in Table 1, corresponding to the maximum operating voltage.

8. HIGH-TENSION CONDUCTORS

8.01. All permanent overhead high-tension systems shall be constructed of metal rods or tubes of sufficient diameter to provide rigidity and prevent corona.

8.02. Sharp edges or points in the high-tension system should be avoided so far as possible in order to minimize brush discharges.

8.03. All parts of high-tension overhead conductors, including meters and stabilizers, shall not be less than a distance of 7.5 feet above the floor for all installations operating below 250 kv. unless surrounded with grounded metal guards or insulating guards in accordance with paragraphs 7.02, 7.03, and 7.04.

8.04. High-tension parts installed in completely inaccessible parts of treatment, diagnostic, or machine rooms may be placed at lower heights than specified in paragraph 8.3.

8.05. All insulating supports for high-tension aerials, high-tension stabilizers, meters, etc., must withstand a dead-weight load of 50 pounds.

8.06. All water coolers for X-ray tubes shall be constructed of metal and the gauge glass (if one is used) suitably protected against breakage by a metal guard when the cooler is in a treatment room.

8.07. The water tubes connecting the water cooler and X-ray tube shall be of metal or rubber tubing covered with a tightly fitting metal sheath.

8.08. If a high-tension switch is used it shall be so constructed that only one set of apparatus can be connected at one time. High-tension switches for controlling apparatus in separated rooms shall have a suitable automatic signal which indicates before operation in each room so controlled. When possible such high-tension switches should be inoperable except when the main generator circuit is open.

9. HIGH-TENSION LEADS TO TUBES

9.01. Permanent high-tension leads to X-ray tubes should be used when possible.

9.02. Temporary leads to X-ray tubes shall be of stranded wire and so arranged as to prevent accidental disconnection.

9.03. If the leads are not detached from the overhead high-tension conductors when not in use, the lowest hanging part thereof shall comply with paragraph 8.03.

9.04. In installations having movable and easily accessible high-tension leads, precautions shall be taken that such leads are never at a distance from tube stands, apparatus, and metal parts less than 1.2 times the distance given in Table 1 for the voltage used.

9.05. When the patient is not fully protected from easily accessible high-tension leads by a suitable grounded metal barrier, the distance between high-tension parts and patient shall be at least twice the distances given in Table 1 for the voltage used.

9.06. In appliances for fluoroscopy or radiography where the tube is below or behind the table or stand, the connecting leads to the tube shall be shielded by a suitable grounded metal guard or insulating guard in compliance with paragraphs 7.01, 7.02, and 7.03. When so-called "masts" are employed, they shall also be surrounded by a grounded metal guard.

9.07. When using an X-ray tube having any exposed high-tension parts, the table shall be insulated from ground by suitable material capable of withstanding 3/2 the maximum working voltage to ground.

9.08. Metal parts of X-ray apparatus, such as tube stands, transformer tanks, motors, controls, etc., shall be permanently grounded to a water pipe through at least a No. 6 B. & S. gage wire or the equivalent. This wire must be suitably protected against accidental breakage.

III. X-RAY EQUIPMENT IN ANAESTHETIC ROOMS

10. SPECIAL REQUIREMENTS IN ADDITION TO SECTIONS 1 TO 9

10.01. Inflammable anesthetics shall include: Ether, ethylene, propylene, ethyl chloride, and nitrous oxide when used in conjunction with ether.

10.02. All open high-tension generating equipment shall be located in a well-ventilated room completely isolated from the anesthetic room, and any connecting doors or windows shall be effectively air-tight. (The doors should close against soft rubber or felt padding.)

10.03. A completely self-contained transformer and X-ray tube unit in an effectively air-tight inclosure is recommended (though not required) for use in all anesthetic rooms.

10.04. Foot switches and all other control devices shall be inclosed in a completely vapor-proof container in accordance with section 3203 of the 1930 National Electrical Code.

10.05. The committee indorses the Recommended Safeguards for the Installation and Operation of Anesthetic Apparatus Employing Combustible Anesthetics, by the National Board of Fire Underwriters, June 1, 1929.

IV. STORAGE OF X-RAY FILM

11. GENERAL REMARKS

11.01. Regulations of the National Board of Fire Underwriters for the Storage and Handling of Photographic and X-ray Nitrocellulose Films, of July 15, 1930, shall be adhered to in detail.

11.02. The committee gives its unqualified indorsement to the sole use of film of slow-burning or safety-base (cellulose acetate) type. It is specifically pointed out that such film constitutes no greater fire hazard than ordinary newspaper in the same form.

11.03. The regulations of the Board of Underwriters as given below apply only to the use of nitrocellulose film.

11.04. The following paragraphs are extracted from the regulations cited in paragraph 11.01:[1]

11.05. Film of a slow burning or safety base (cellulose acetate) does not have a fire hazard characteristic of nitrocellulose film. The use of film of slow burning or safety base (cellulose acetate) is recommended for hospitals and similar institutions, doctors' offices, X-ray laboratories, and the like. The cellulose acetate film (safety film) is in a class with ordinary newsprint paper in similar form and quantity in respect to the hazard to life of its smoke and fumes in a fire. Where large amounts are stored the use of steel filing cabinets is recommended.

11.06. Where both kinds of film are used or stored at the same location in any building the requirements for nitrocellulose film shall apply.

11.07. These regulations, based on available knowledge and field experience, prescribe such methods for protection

[1] These paragraphs have been reprinted by permission of the National Board of Fire Underwriters. The numbering of the paragraphs has, however, been altered so as to conform to the system used in these recommendations. Paragraphs not related directly to the storage of X-ray film have been omitted.

against the hazards of handling and storage of photographic and X-ray nitrocellulose films as are judged to be of practicable application in types of buildings and occupancies where such hazards are encountered, but it should be recognized that in the event of fire involving the decomposition of such quantities of films as it is contemplated may be stored in the vaults, cabinets, or containers covered by these regulations a hazard to life remains depending upon the care and supervision exercised and the precautions taken in the handling of the film.

11.08. Safety photographic and X-ray film (cellulose acetate base) may be identified by the marking on the edge of the film. This marking shows plainly before and after developing. Where film is not so marked it should be inspected to determine whether it is of the safety acetate or nitrate type.

11.09. These regulations do not apply to: Safety film (cellulose acetate base) and dental X-ray film.

12. HOSPITALS AND SIMILAR INSTITUTIONS, DOCTORS' OFFICES, AND X-RAY LABORATORIES

12.01. Storage of unexposed films shall be in unopened I. C. C. shipping containers or in approved cabinets vented to the outside air or in vented storage vaults or outside storage houses. Only one I. C. C. shipping container of each size shall be opened at one time. Where the total aggregate exceeds 50 cubic feet, storage shall be in a vented storage vault in accordance with sections 13.12 to 13.27, or in an outside storage house in accordance with sections 13.28 to 13.34.

13. STORAGE OF FILM NEGATIVES

(The following paragraphs apply only to film negatives (developed film)):

General.

13.01. Storage of film negatives in basements is prohibited.

13.02. Film negatives in storage or in process of handling shall be kept in heavy manila envelopes, not exceeding 12 films to an envelope. Expanding envelopes shall not be used.

Portrait and Commercial Studios.

13.03. Film negatives shall be kept in approved vented cabinets (see secs. 13.05 to 13.11) or in vented storage vaults or outside storage houses. Not more than 250 pounds shall be stored in any single cabinet. Where the film stored exceeds 1,000 pounds it shall be in vented storage vaults (see secs. 13.12 to 13.27), or in a detached structure or roof vault (see secs. 13.28 to 13.34).

NOTE.—The following table may be used as a guide in computing the weight of film:

Number of negatives	Size	Approximate weight
	Inches	*Pounds*
1,000	14 by 17	118
1,000	10 by 12	60
1,000	8 by 10	40

(Other sizes in proportion to area.)

Hospitals and Similar Institutions, Doctors' Offices, and X-ray Laboratories.

13.04. All film negatives shall be stored in approved vented cabinets in accordance with sections 13.05 to 13.11, or in outside storage houses. Approved cabinets shall be provided convenient to X-ray rooms for current use. Storage in excess of 500 pounds of film shall be in an outside storage house in accordance with sections 13.28 to 13.34. Storage house may be located on the roof. Vaults shall not be located within the building.

Vented Cabinets.

13.05. No single cabinet shall exceed 10 cubic feet capacity. Not over 250 pounds of films shall be kept in any single cabinet.

NOTE.—Each insulated vented unit is considered as a single cabinet.

13.06. All cabinets shall be of approved insulated construction.

NOTE.—Under average conditions of storage of film in manila envelopes (six films to the envelope), 1 cubic foot of storage repre-

sents approximately 20 pounds of film, due allowance being made for space not occupied by film. Actually 1 cubic foot of film negatives in envelopes weighs from 60 to 64 pounds.

13.07. Cabinets shall be equipped with at least one automatic sprinkler in each compartment (unit) unless specifically approved for use without automatic sprinklers.

13.08. Each cabinet shall be provided with a vent to the outside of the building. For a cabinet of 10 cubic feet inside volume the vent opening shall be not less than 56 square inches. For smaller cabinets the vent area shall be in proportion to the volume, except that no cabinet shall have a vent area of less than 14 square inches. The vent of the cabinet shall be so constructed or protected by a substantial metal grid as to prevent stoppage of vent in case of combustion or decomposition of film contents.

13.09. The vent areas given in these regulations are based upon a vent for a pipe length of 10 feet. For longer lengths due allowance shall be made for friction loss and turns in pipe.

13.10. The outlet of each vent shall be above roof and at least 25 feet from doors, windows, other openings, or fire escapes.

13.11. Vent flues shall be of construction equivalent to that required for chimneys or of riveted sheet metal not thinner than No. 18 U. S. gage; if inside the building, they shall be covered with 1 inch of approved heat insulating material and not nearer than 9 inches to any combustible material.

Vented Storage Vaults (Inside).

13.12. No vault shall exceed 750 cubic feet in actual storage capacity, including aisles.

13.13. The floor and walls of every vault shall be made of brick at least 8 inches thick or of reinforced concrete at least 6 inches thick. In fireproof buildings the building floor may be used as the floor of the vault if equivalent in fire resistance to the requirements given above. Vaults shall be supported by masonry or steel of sufficient strength to carry the load safely. Beams shall rest at both ends of steel girders, iron or steel columns, or walls or piers of masonry. The supports shall afford at least four hours' protection as

determined by the Standard Fire Test Specifications. Hollow tile shall not be used for foundation walls.

NOTE.—Where the design of the buildings is such that an excessive floor load would result from having the film vault filled with water, the film vault shall be provided with one or more scuppers, giving a total area of outlet equal to 3 square inches for each sprinkler head installed in the film vault. A depth of 10 feet of water will result in a floor load of 626 pounds per square foot.

13.14. The roof of vault, if inside the building, shall be an independent reinforced-concrete roof at least 6 inches thick; in a fireproof building, where the floor above is equivalent to this, it may serve as the roof if side walls are rigidly tied into it; in construction of this type a false ceiling construction of metal lath and cement plaster 1 inch thick, or the equivalent, and with no openings to the concealed space above, may be used to limit the total interior vault space to 750 cubic feet. Vent may extend through this false ceiling and concealed space.

13.15. Vaults shall not be provided with skylights or glass windows other than as specified under vents.

13.16. Proximity to boilers, stacks, or other sources of heat shall be avoided. Where heating is necessary to prevent freezing, coils shall be provided at the ceiling over aisle space. Pipes and radiators shall be so screened that film can not come within 2 feet of them. Only hot water or low pressure steam heating shall be allowed, with automatic control limiting pressure to 10 pounds per square inch and temperature to not in excess of 100° F. No indirect heating, nor arrangement employing fans for air circulation, shall be employed.

13.17. Door openings in vault shall be protected by an approved vault door of 4-hour or longer classification. It shall be kept closed except when in use.

13.18. In lieu of the above, door openings may be protected on each side by an approved fire door suitable for use in class B situations. The interior door shall be automatic. The outer door shall be of the swing type and close into an approved frame. It shall be self-closing, and if fastened open shall be arranged to close automatically in case of fire originating in or out of vault.

NOTE.—A vault door, while not certain of being kept shut, will provide superior protection against the passage of fumes.

13.19. Films in vaults shall be stored upon shelves, or in cabinets which are designed to permit the effective distribution of water from automatic sprinklers and are specifically approved for use in vaults. Ordinary filing cabinets shall not be used in vaults. If wooden shelving is used, this shall be of slatted construction, with slats not over 4 inches wide and spaced at least 1 inch apart. If steel shelving is used, the shelves shall be perforated to the amount of at least 20 per cent of the shelf area. Shelves of iron pipe, angles or similar construction shall have open spaces to the amount of at least 20 per cent of the shelf area. Vertical incombustible partitions, equivalent in heat insulation and durability to three-eighth-inch hard asbestos, shall be provided to divide shelving into sections not over 3 feet wide and so placed as not to obstruct distribution from sprinkler heads.

13.20. Each vault shall be equipped with approved automatic sprinklers or with an open-head sprinkler system controlled by heat-actuated devices, the system to be approved for this particular use. Sprinklers shall be arranged according to the sprinkler regulations in so far as applicable. The area to be covered by each sprinkler head shall not exceed 15 square feet of floor area. Proper baffles shall be provided between heads.

13.21. Substantial metal grids of approximately 2-inch mesh shall be installed to prevent clogging or stoppage of vent and piling of film above the top of the shelving or cabinets higher than 2 feet below the sprinklers, and thus interfering with distribution of water.

13.22. Each vault shall separately vent to the outer air, with a vent having a minimum effective sectional area of 150 square inches per 1,000 pounds of film capacity. For a standard vault of 750 cubic feet containing 10,000 pounds of film the vent opening shall be 1,500 square inches.

13.23. The outlet of each vent shall be above roof and at least 25 feet from doors, windows, other openings, or fire escapes.

13.24. All horizontal or vertical flues inside of the building shall be of 5-inch reinforced concrete or of a construction equivalent to that of chimneys.

13.25. Exterior metal flues shall be of a construction equivalent to that of smokestacks.

13.26. Each vent opening directly through an exterior wall shall be protected against the weather by single-thickness glass (one-sixteenth inch thick), painted a dark color, or by other incombustible fragile material, in a sash arranged to open outward automatically in case of fire by the use of an approved releasing device placed inside the film storage. The area of the glass shall be the effective sectional area of the vent opening. No pane of glass shall be smaller than 200 square inches.

13.27. A light wire screen not coarser than one-eighth-inch mesh shall also be placed over each vent, so arranged as not to interfere with the automatic operation of the sash. Bars or screen, if used to prevent burglary or injury to contents, shall not have a mesh of less than 4 inches, shall be located inside the light wire screen, and shall give a net opening equal to that called for under paragraph 13.22.

Outside Storage Houses.

13.28. Buildings should preferably be located at least 100 feet away from any other building or combustible material. If on a roof, or within 100 feet of any other building or combustible material stored in the open, the building shall have all walls equivalent in fire resistance to 4 inches of concrete, or 3-cell 8-inch tile. Door openings in such walls shall be protected by approved fire doors suitable for use in class B situations. Skylights shall be protected in such a manner as to prevent radiated heat or flying brands from igniting the contents of the building.

13.29. Buildings exceeding 750 cubic feet capacity shall be divided into sections of not over 750 cubic feet by unpierced walls of construction equivalent to that required for the exterior walls.

13.30. In hospitals access to the outside storage rooms shall be by means of a balcony or vestibule open to the outside air, with no direct communication between the room and the building.

13.31. Heating shall be in accordance with section 13.16.

13.32. Interior equipment shall be in accordance with section 13.19.

13.33. If the storage house is located within 100 feet of any other building, automatic sprinkler protection shall be provided in accordance with sections 13.20 and 13.21.

13.34. Vents shall be in accordance with sections 13.22 and 13.23.

14. GENERAL

(Applies to both unexposed films and film negatives.)

14.01. All wiring and equipment shall conform to the National Electrical Code. See article 32, Hazardous Locations.

14.02. Only incandescent electric lights shall be permitted. In storage rooms these shall be protected with either substantial wire guards or vapor-proof globes, or both.

14.03. The use of portable lights on extension cords in any storage room or vault is prohibited.

14.04. Illuminators shall be so built that the diffusing glass does not become overheated. There shall be no unnecessary display of negatives in lighted illuminators.

14.05. Smoking shall be prohibited in rooms where film is handled or stored. Conspicuous "No smoking" signs shall be posted in prominent places.

14.06. No films shall be stored within 2 feet of steam pipes, radiators, chimneys, or other sources of heat.

14.07. Film driers, if used, shall be of approved type.

14.08. First-aid fire appliances of types using water or water solutions shall be provided for the pprotection of all rooms containing film.

NOTE.—The following types of extinguisher are considered suitable: Soda-acid, pump tank, calcium chloride, and loaded stream. Small hose equipment is likewise suitable.

14.09. Discarded film shall be stored and handled in the same manner as other film until removed from the premises.

V. OPERATING RULES

15. RULES FOR TECHNICIANS, NURSES, ETC.

15.01. A copy of these rules shall be given to every X-ray worker, whether temporary or otherwise, upon entering service. A signed receipt stating that the rules are understood shall be given to the physician in charge of the department.

15.02. A copy of these rules, together with a copy of first-aid instructions for electrical shock, shall be posted conspicuously in all principal X-ray rooms.

15.03. Protective gloves and aprons, even though in compliance with these recommendations, do not afford adequate protection. Consequently, care shall be taken at all times not to expose the body unnecessarily to radiation.

15.04. Lead rubber becomes hard and brittle with age, and all such protection should be tested at regular intervals for possible cracks and imperfections. This test should be made radiographically or radioscopically.

15.05. Radioscopic work should be performed in the minimum time possible, using the lowest X-ray intensity and smallest aperture consistent with demands. It is important, however, that the fluoroscopist use sufficient X-ray intensity so that he can see without eyestrain.

15.06. The omission of any protective devices for the sake of expediency of operation shall be strictly forbidden.

15.07. Before touching any X-ray generator or high-tension part, particular care shall be taken to make sure that the main-line switch is open and the whole apparatus is disconnected from the power line.

15.08. In the case of equipment having high-tension condensers, care shall be taken that both sides of the high tension are actually and securely grounded before touching any part thereof.

15.09. If the transformer and controls are located in a remote room, a plaque reading "Do NOT TOUCH" shall be hung over the main-line switch when it is necessary to touch high-tension parts in another room.

15.10. Where several appliances for treatment or examination may be connected to a common high-tension system, care shall be taken that conductors to all idle equipment are disconnected.

15.11. Where the machine operation depends upon two persons, a distinctly audible or visible signal shall be given by the operator before throwing on the high tension, and a return signal received from the person using the equipment.

15.12. Any acoustical or optical signal system for protective purposes should be checked daily before commencing work.

15.13. The main switch should be opened immediately upon completion of the X-ray work, or when the machine is not in actual use.

15.14. The high-tension overhead system should be examined frequently for possible faulty insulators or loose parts.

15.15. A daily check shall be made, to be certain that no idle flexible high-tension leads extend below the minimum prescribed height above the floor.

15.16. All grounding connections shall be examined weekly.

15.17. All high-tension barriers shall be examined frequently. When possible, this should be done when cleaning the apparatus.

15.18. In case of fire in the X-ray or control rooms, or in any part of the building, all X-ray apparatus should be immediately disconnected from the mains by opening the main power line switch.

15.19. All workers should be thoroughly familiar with the Schaeffer prone pressure method of resuscitation in case of electric shock, and a set of such instructions should be posted conspicuously in each main room. Above the description of the method should be placed the instructions:

This hospital may be provided with pulmotor or other resuscitation apparatus. Do not wait to send for it, but proceed immediately with the Schaeffer prone pressure method.

15.20. How to give artificial respiration by the prone pressure method:[2]

1. Lay the patient on his belly, one arm extended directly overhead, the other arm bent at elbow and with the face turned outward and resting on hand or forearm, so that the nose and mouth are free for breathing. (See fig. 1.)

2. Kneel straddling the patient's thighs with your knees placed at such a distance from the hip bones as will allow you to assume the position shown in Figure 1.

Place the palms of the hands on the small of the back, with fingers resting on the ribs, the little finger just touching the lowest rib, with the thumb and fingers in a natural position, and the tips of the fingers just out of sight. (See fig. 1.)

3. With arms held straight, swing forward slowly, so that the weight of your body is gradually brought to bear upon the patient. The shoulder should be directly over the heel of the hand at the end of the forward swing. (See fig. 2.)

[2] Reprint from the Public Health Reports, 43, No. 3, pp. 111–112; Jan. 20, 1928.

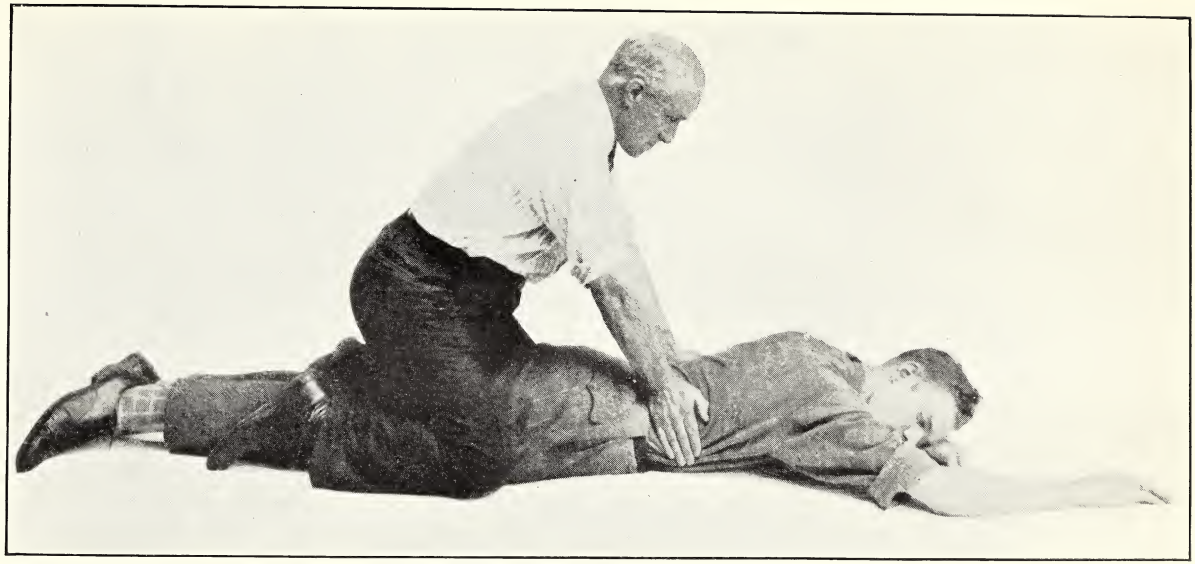

FIGURE 1.—*Resuscitation position 1*

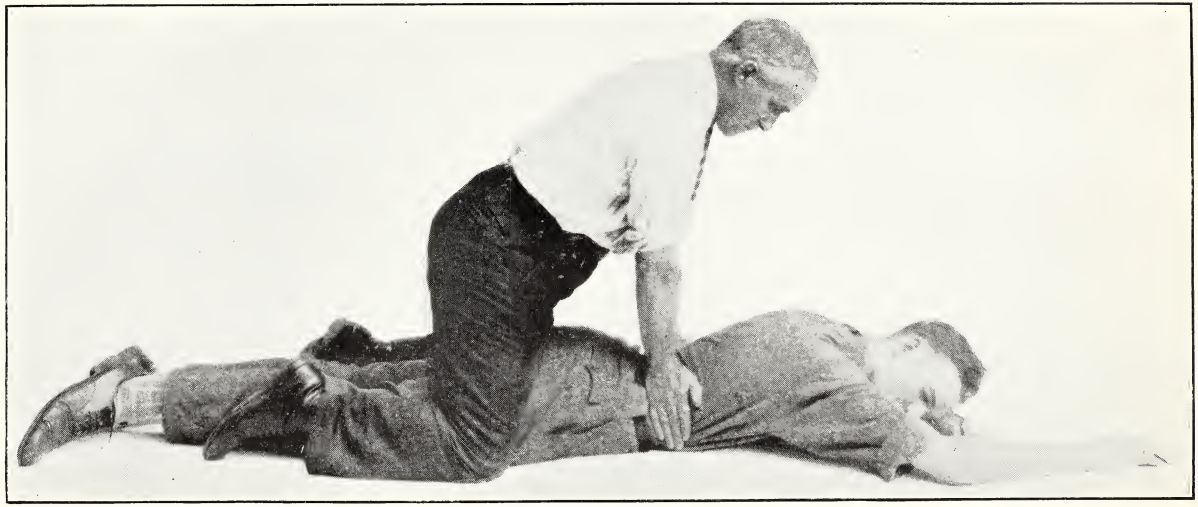

FIGURE 2.—*Resuscitation position 2*

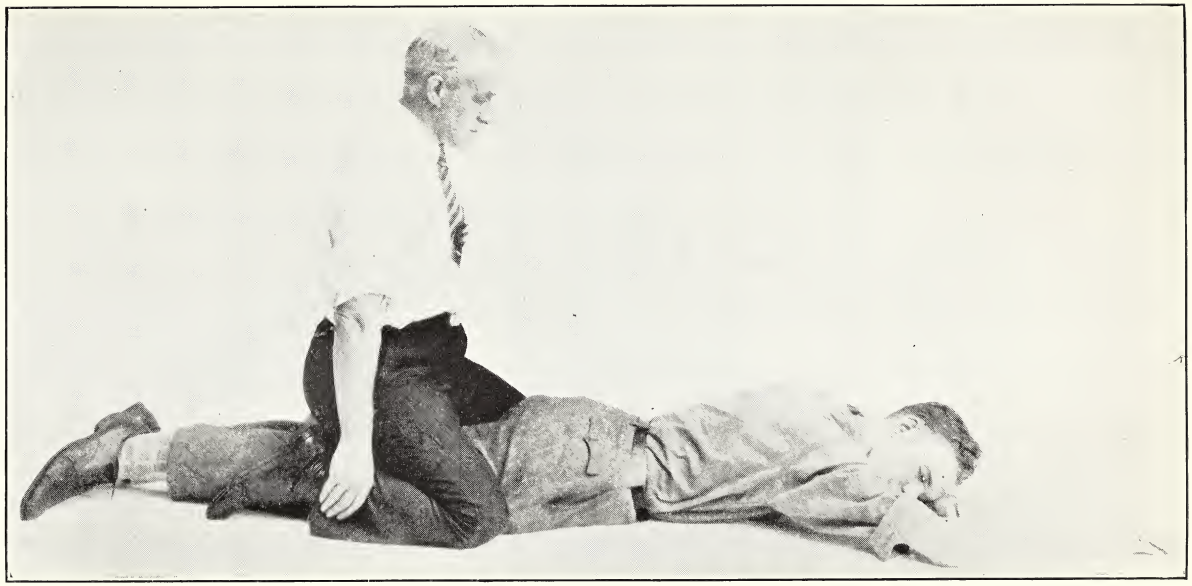

FIGURE 3.—*Resuscitation position 3*

Do not bend your elbows. This operation should take about two seconds.

4. Now immediately swing backward, so as to remove the pressure completely. (See fig. 3.)

5. After two seconds swing forward again. Thus repeat deliberately 12 to 15 times a minute the double movement of compression and release, a complete respiration in four or five seconds.

6. Continue artificial respiration without interruption until natural breathing is restored; if necessary, four hours or longer, or until a physician declares the patient is dead.

7. As soon as this artificial respiration has been started and while it is being continued an assistant should loosen any tight clothing about the patient's neck, chest, or waist. Keep the patient warm. Do not give any liquids whatever by mouth until the patient is fully conscious.

8. To avoid strain on the heart when the patient revives, he should be kept lying down and not allowed to stand or sit up. If the doctor has not arrived by the time the patient has revived, he should be given some stimulant, such as one teaspoonful of aromatic spirits of ammonia in a small glass of water or a hot drink of coffee or tea, etc. The patient should be kept warm.

9. Resuscitation should be carried on at the nearest possible point to where the patient received his injuries. He should not be moved from this point until he is breathing normally of his own volition and then moved only in a lying position. Should it be necessary, due to extreme weather conditions, etc., to move the patient before he is breathing normally, resuscitation should be carried on during the time that he is being moved.

10. A brief return of natural respiration is not a certain indication for stopping the resuscitation. Not infrequently the patient, after a temporary recovery of respiration, stops breathing again. The patient must be watched, and if natural breathing stops, artificial respiration should be resumed at once.

11. In carrying out resuscitation it may be necessary to change the operator. This change must be made without losing the rhythm of respiration. By this procedure no confusion results at the time of change of operator, and a regular rhythm is kept up.

16. RULES FOR PHYSICIANS IN CHARGE

16.01. The efficiency of X-ray protection and protective devices shall be examined upon installation and yearly thereafter. This shall be accomplished with a fluorescent screen fitting closely over the eyes. The detection of any fluorescence by the well, dark adapted eye shall be considered a hazard and be remedied.

16.02. For the purpose of providing safety for the working personnel, it is recommended that such annual inspection of X-ray protection be conducted by an expert in such work.

16.03. At least every four months each worker shall be supplied with a dental X-ray film half covered with lead foil, which shall be worn on the breast continuously, with the film side out, for 15 working days. If, upon development, appreciable darkening of the exposed part of the film is indicated, the cause therefor shall be investigated and eliminated.

16.04. Circuit-breakers should be examined monthly to be certain that the overload adjustment is correct.

17. PERSONNEL WORKING CONDITIONS

17.01. It is the duty of the physician in charge of an X-ray department to be responsible for the health and safety of all workers in so far as conditions permit.

17.02. Favorable working conditions shall include provision for workers of ample light and sunshine, fresh air, sufficient spare time, and satisfactory protection.

17.03. Every assistant, technician, and operator should be given at least four weeks' vacation a year with at least two weeks of this consecutively and during the summer months.

17.04. All persons occupied in radiological work should be examined for general radiation injuries yearly. Complete blood counts should be made bimonthly. The results of all tests and examinations should be permanently recorded. It is advisable that all persons be carefully examined before entering radiological work.

For the committee.

LAURISTON S. TAYLOR,
Chairman Advisory Committee
on X-ray and Radium Protection.

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